FEDERAL AID TO FISH RESTORATION

COMPLETION REPORT

MAN-MADE LAKES INVESTIGATIONS

PROJECT NO. F-R-160-R

Study 7008. Assessment of the impact of physical, chemical and biological factors and angling upon bluegill and crappie populations

Job 1. Population characteristics of bluegill, crappie and largemouth bass

Job 2. Physical and chemical components of the ecosystem that may affect bluegill and crappie populations

Job 3. Impact of angler harvest and largemouth bass predation on bluegill and crappie populations

Job 4. Statewide database statistics on bluegill and crappie

Job 5. Management guidelines

Period covered: 1 July 1990 - 30 June 2008
Iowa Department of Natural Resources
Richard Leopold, Director

July, 2008

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Period Covered: **July 1, 1990-June 30, 2008**

Prepared by: ______________________ July 1, 2008
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Fisheries Research Supervisor **Date**

CONSERVATION AND RECREATION DIVISION

Iowa Department of Natural Resources
Richard Leopold, Director

TABLE OF CONTENTS

Study 7008. *Assessment of the impact of physical, chemical and biological factors and angling upon bluegill and crappie populations.*

LIST OF TABLES AND FIGURES

TABLES

Study 7008. *Assessment of the impact of physical, chemical and biological factors and angling upon bluegill and crappie populations.*

FIGURES

Study 7008*. Assessment of the impact of physical, chemical and biological factors and angling upon bluegill and crappie populations.*

LIST OF APPENDICES

Study 7008*. Assessment of the impact of physical, chemical and biological factors and angling upon bluegill and crappie populations.*

STUDY 7008

Assessment of the impact of physical, chemical and biological factors and angling upon bluegill and crappie populations

OBJECTIVE

To determine the importance of lake watershed, lake basin morphology, water quality, predator populations, and angling upon the well-being of crappie and bluegill populations in man-made impoundments.

JOB 1

Population characteristics of bluegill, crappie and largemouth bass

OBJECTIVE

To measure density, size structure, growth, body condition, harvest, and exploitation rates of bluegill, crappie, and largemouth bass at selected Iowa man-made lakes.

JOB 2

Physical and chemical components of the ecosystem that may affect bluegill and crappie populations

OBJECTIVE

To determine the affect of watershed, lake morphology and water quality upon bluegill and crappie density, size structure, growth rate and body condition.

JOB 3

Impact of angler harvest and largemouth bass predation on bluegill and crappie populations

OBJECTIVE

To determine the affect of largemouth bass density, size structure, and angler exploitation upon bluegill and crappie density, size structure, growth rate, and body condition.

JOB 4

Statewide database statistics on bluegill and crappie

OBJECTIVE

To enter findings from study lakes of this investigation into the statewide database of fisheries statistics.

JOB 5

Management guidelines

OBJECTIVE

To prepare a completion report on the investigation and provide a fisheries management plan for various lake classes.

COMPLETION REPORT

RESEARCH PROJECT SEGMENT

STATE: Iowa

JOB NO.: 1, 2, 3, 4 and 5

TITLE: Assessment of the Affect of Physical, Chemical and Biological Factors and Angling Upon Bluegill and Crappie Populations

ABSTRACT

Quality crappie and bluegill populations at 23 study lakes were related to populations of largemouth bass, lake morphometry, water quality, angler harvest, watershed size, land use, and nutrient loading. Factors most responsible for creating quality panfish angling in Iowa man-made lakes were measured. Indices of well-being were developed for bluegill, crappie, and largemouth bass. These parameters were based upon body condition, growth, and size structure. Quality of largemouth bass populations were not significantly related to quality of bluegill or crappie populations. Lake shape, however, was closely related to the well-being of bluegill and crappie populations. Deep lakes with high mean basin slopes were associated with bluegill populations characterized by above average growth, body condition, and good size distribution. These bluegill characteristics were also associated with small watershed:lake area ratios. Crappie well-being indices were positively associated with low watershed:lake area ratios, low phosphorous concentrations, good water clarity and large, deep lakes. Water quality was adversely affected by watershed size and high watershed:lake ratios. Largemouth bass population characteristics were affected by anglers, whereas, the quality of bluegill and crappie populations were not. Agricultural Nonpoint Source Pollution (AGNPS) modeling showed fish well-being indices with the lowest rankings were found in lakes with the highest watershed sediment and nutrient loading coefficients. Information from this study will be used to classify and rank constructed lakes in terms of priority for protection and restoration. These finding will also assist lake managers identify and apply best management practices based on lake morphometry, watershed characteristics, water quality, biological health and associated lake-based recreation.

INTRODUCTION

Crappie and bluegill are the most often caught fish in Iowa and comprised 46% of the 1994 statewide harvest as estimated by a telephone survey (University Northern Iowa 1995). Popularity of these panfish also ranked high, outranked only by channel catfish, largemouth bass and walleye. Statewide, 20% of the licensed Iowa anglers preferred catching bluegill or crappie. Estimated harvest in 1994 was nearly 19 million fish, and panfish comprised about 50% of the harvest in southern Iowa. It is common for crappie or bluegill to comprise 85% of the fish harvested by anglers from constructed lakes (Mitzner 1978; 1981).

The popularity of panfish and dominance of crappie and bluegill in the sport fish harvest are largely due to the health and vigor of these populations in Iowa's waters. Some lakes produce quality angling with very little cost and effort, while other lakes produce fish lacking angler appeal, regardless of liberal and costly application of traditional fisheries management techniques. The purpose of this investigation is to identify and delineate factors responsible for such disparity in panfish populations, measure the magnitude of these influences, and provide information necessary to predict the quality of bluegill and crappie fishing provided by a variety of Iowa lakes. The study is also designed to assess and predict the affects of a variety of management strategies on the quality of these fisheries.

Previous investigations provided the impetus for this investigation; foremost was work done by Hill (1991). He found lake basins, which contained the most angler acceptable fish, were steep-sided and subjected to very little siltation. Buck (1956), Gardener (1981) and Mitzner (1991) also delineated the affect of physical factors upon the well being of bluegill and crappie populations. Factors described by these authors included water level, temperature, turbidity, wind, and substrate.

Biotic factors affecting bluegill and crappie populations as reported in the literature include available food supply and density of predator fish. Control of overabundant panfish populations by stocking predators was reported by Snow (1968), Gabelhouse (1984a), Boxrucker (1987), Savino and Stein (1982), and Hill (1981). Mechanical removal of bluegills and crappies to reduce densities and improve growth of remaining fish was marginally successful, but at least 50% of the population biomass must be removed, and results were short-lived (Beyerle and Williams 1972; Houser and Grinstead 1961). Rutledge and Baron (1972) produced a comprehensive bibliography on fish removal, including a case history study on white crappies.

Another biotic factor addressed by Coble (1988) was the affect of angling on bluegill populations. He reported that exploitation rates in excess of 27% would substantially alter the total mortality rate and size structure of bluegill populations. Colvin (1985) outlined Missouri's crappie management program of harvest restrictions. Mosher (1985) hypothesized that dense populations of largemouth bass and walleye may limit recruitment of crappie in Kansas lakes, allowing even modest crappie exploitation to overharvest larger crappie. Conversely, lakes without dense predator populations may have slower-growing crappie populations and attract fewer anglers, which perpetuate crowded, slow-growing conditions. This is especially true when anglers are reluctant to harvest small crappie (Mosher 1985). Other authors, however, showed harvest restrictions on bluegills and crappies were not needed or were counter-productive (Snow 1982; Schneider 1973; and Partriarche 1968).

The problem of slow growth and unappealing bluegill and crappie populations in Iowa lakes is a major concern of anglers and resource managers. A major focus of this investigation will be the physical shape of the lake basin, water quality, and lake watershed characteristics. These factors, along with influences of anglers and predator populations, will be related to the well being of bluegill and crappie populations. The information obtained will expand our efforts beyond traditional fisheries management activities and help managers address important ecological factors that limit angling opportunity for quality bluegill and crappie.

STUDY AREAS

Each of the study lakes (Table 1) contained the following target species: bluegill, crappie, and largemouth bass. These lakes also contained channel catfish, green sunfish, and bullhead. Additionally, some lakes contained common and/or grass carp.

TABLE 1.—Physical characteristics of 23 study lakes.

Lake	Area Acres	Maximum depth (ft)	Mean depth (ft)	Mean Basin Slope	Volume ac-ft	Shoreline Development	Volume Development	Watershed Lake area ratio
Ahquabi	109	17.5	8.2	2.5	889	9.221	1.42	30.6
Anita	182	28	12	5.7	2,227	4.05	1.31	13.2
Bob White	89	14	5	2.7	444	2.97	1.07	38.2
Green Valley	337	24	10	3.4	3,574	3.73	1.38	12.5
Hawthorn[1]	172	32	12	5.4	2,267	3.4	1.13	19.4
Iowa[1]	86	32	12	4.3	987	2.12	1.12	15.5
Keomah	84	22	10	4.0	846	2.91	1.37	22.1
Lacey-Keo[1]	21	28	12	11.3	258	1.98	1.26	34.4
Mariposa[1]	18	16	7	5.2	135	1.53	1.35	31.0
Miami	135	24	10	5.5	1,336	3.29	1.19	28.9
Nine Eagles	63	32	14	7.6	863	2.3	1.29	19.0
Pahoja[1]	63	30	11	2.5	673	2.98	1.04	62.5
Pollmiller[1]	18	30	12	8	213	2.63	1.19	13.1
Prairie Rose	219	24	10	5.1	2,083	3.04	0.82	21.0
Red Haw	61	40	14	10.0	948	3.48	1.08	14.0
Rock Creek	492	20	8		3704	3.14	1.18	53.8
Slip Bluff[1]	16	24	12	12.4	198	2.29	1.55	14.4

TABLE 1.—Continued.

Lake	Area Acres	Maximum depth (ft)	Mean depth (ft)	Mean Basin Slope	Volume ac-ft	Shoreline Development	Volume Development	Watershed Lake area ratio
Smith[1]	59	10	5	2.3	315	1.82	1.6	18.6
Swan	112	14	6	2.2	643	1.78	1.19	6.1
Union Grove[1]	105	16	8	2.3	788	1.92	1.6	63.2
Viking[1]	137	48	15	8.6	2,059	3.51	0.94	15.6
Williamson Pond	30	18	8	5.5	237	2.06	1.37	46.8
Yellow Smoke[1]	39	26	11	6.2	325	3.56	1.3	39.9

[1]Sampled by Fisheries Management personnel.

METHODS

Lakes included in this study represented a wide range of ecological conditions within Iowa's constructed lakes. The physical, chemical and biological characteristics of each study lake and watershed were examined, particularly relationships between fish well-being, harvest, lake morphology, watersheds and water quality.

Fish Populations

Population density and biomass of bluegill, crappie, and largemouth bass were estimated by sequential mark and recapture efforts conducted May through June. The exception was Swan, Anita, Nine Eagles, Ahquabi, and Prairie Rose Lakes, where crappie abundance was estimated in September. Fish were sampled, finclipped, and released for subsequent recapture. A combination of electrofishing gear and fyke nets was used to sample fish.

Age, growth, size structure, and weight-length statistics were derived from monthly samples. Otoliths were taken from fish at lakes with stunted or slow-growing populations while scale samples were taken from fish at the remaining lakes. Growth calculations were performed with DisBcal (Frie 1982); relative weight (W_r) was based on standards by Newmann and Murphy (1992). Size structure was described by the relative stock density (RSD) incremental method (Gabelhouse 1984b). The three size categories used in this investigation included stock, quality and preferred. Each category was a percent of the whole sample, and the three categories summed to 100%.

Harvest statistics were estimated from stratified random creel survey methods conducted mid April through mid October. Effort was a function of hourly instantaneous counts, length of fishing day, and number of days per month. Total sport fish harvest was estimated as the product of catch per hour and total effort during the period. Anglers sampled were stratified by weekend/weekday and boat/shore. Fishing days were divided equally into two parts, early and late, with independent expansion for each segment.

Lake Morphology and Water Quality

Physical characteristics of the lakes were derived from measurements and calculations made by Bachmann et al. (1994). Characteristics included area, length of shoreline, maximum and mean depth, volume, shoreline development, watershed:lake area ratio, mean basin slope, and volume development. Equations to calculate these indices were given by Hutchinson (1975).

Lake water quality was measured at each lake three times during the summer, May through August in 1979, 1990, and 2000 - 2005. Parameters determined for the upper 10 feet of the water column included field measurement of turbidity (Secchi disc depth), temperature, dissolved oxygen, and laboratory analysis of chlorophyll *a*, total suspended solids, total phosphorous, and total nitrogen according to APHA, AWNA, WPCF, (1976) standards.

Watershed Characteristics

Many watersheds (Ahquabi, Bob White, Miami, Red Haw, Rock Creek, Swan, Union Grove, and Williamson Pond) have been assessed with a PC-based Agricultural Nonpoint Source Pollution (AGNPS) Model, which requires the following information:

- curve number
- slope shape factor
- field slope length
- channel slope
- channel sideslope
- soil erodibility factor
- cover and management factor
- support practice factor
- surface condition constant
- aspect, direction of drainage
- soil texture
- fertilization level
- fertilization availability factor
- point source level
- gully source level
- chemical oxygen demand factor
- impoundment factor
- channel indicator

Each watershed was divided into 10-acre or 40-acre units and the above parameters were described for each of the units. Information was obtained and digitized from soil maps, USGS maps, and NRCS photos. Ground observations were also used to obtain additional information needed in our assessment.

Statewide database

The Limnology Laboratory at Iowa State University (ISU) initiated a water quality survey of Iowa's principal recreational lakes in May 2000 and continuing to date. Included in this study are 132 of Iowa's lakes. Each of these lakes was sampled three times each year. In addition to water quality parameters, phytoplankton and zooplankton composition in each of these lakes was determined. Along with this study, efforts are being made to develop digital bathymetric maps and sediment profiles for each lake.

Fisheries management and research personnel met in March, 2001 and provided the impetus for development of the Fisheries Statewide Database which was integrated into the water quality database developed by ISU. The meeting also provided an opportunity to set protocol for sampling. The purpose of the database was to store, analyze, retrieve, and report information collected from fisheries surveys. Detailed standardized sampling protocols used during the surveys were outlined in "Standard Gear and Techniques for Fisheries Surveys in Iowa, 1995". The primary metrics included growth (length at age and back-calculated), size structure (proportional stock density and relative stock density), body condition (W_r), relative abundance (catch-per-unit effort), and species caught during these surveys or known to be present in the lake.

Each of the 132 lakes was sampled at least once and a schedule was prepared to ensure all lakes were sampled during a four-year sampling period (2001-2004). All sampling was conducted in the fall (September-October); however, supplemental spring sampling was necessary for northern pike and yellow perch. A total of nine target species were selected for inclusion in the database (Table 2). These species were selected because they are abundant in Iowa and either directly affect water quality (e.g. common carp), or are affected by it. Other important fish species (channel catfish, e.g.) were included if sufficient numbers are caught for valid analysis.

TABLE 2.—Minimum sample size, stock size, and preferred aging structures for target fish species.

Species	Sample size for lengths and weights	Stock size (inches)	Preferred aging structure	Sample size for age-growth structures
Black Bullhead	50	6	Pectoral spine	At least 5 fish per 1/2 inch group
Black Crappie	50	5	Scales, otoliths	At least 5 fish per 1/2 inch group
Bluegill	50	3	Scales, otoliths	At least 5 fish per 1/2 inch group
Common Carp	50	11	Scales, dorsal spine	At least 5 fish per inch group
Largemouth Bass	50	8	Scales, Pelvic spines	At least 5 fish per inch group
Northern Pike	50	14	Scales, Pelvic spines	At least 5 fish per inch group
Smallmouth Bass	50	7	Scales, Pelvic spines	At least 5 fish per inch group
White Crappie	50	5	Scales, otoliths	At least 5 fish per 1/2 inch group
Yellow Perch	50	5	Anal spines	At least 5 fish per 1/2 inch group

Results

Fish Populations

<u>Abundance and Biomass</u>

Twenty eight population estimates were completed at 12 study lakes. The highest density of bluegills was found at Lake Ahquabi, 1998, with an estimated 2,391 fish per acre. The greatest biomass occurred at Ahquabi, estimated at 354 lbs per acre in 1997 (Table 3). Lowest bluegill abundance was measured at Green Valley, 1996, at 27 per acre. Low biomass estimates occurred at Green Valley (1996), Red Haw, Keomah, Rock Creek, and Williamson with values < 40 lbs per acre. Average estimated bluegill density and biomass were 717 fish per acre and 120 lbs per acre for the lakes sampled.

TABLE 3.—Population and biomass estimates of bluegills (≥3 in), crappies (≥5 in) and largemouth bass (≥8 in) at 12 study lakes.

		Bluegills		Crappies		Largemouth Bass	
Lake	Year	*N*/ac	lbs/ac	*N*/ac	lbs/ac	*N*/ac	lbs/ac
Ahquabi	1997	2,373	354	102	22	148	110
Ahquabi	1998	2,391	317	51	27	21	9
Ahquabi	1999	1,687	293	26	11	131	69
Ahquabi	2000	1,775	276	--	--	89	65
Ahquabi	2001	1,752	331	8	3	231[1]	86
Ahquabi	2002	625	118	7	3	161	117
Anita	1992	356	86	71	20	35	42
Bobwhite	1992	679	129	--	--	27	22
Green Valley	1993	257	62	63	23	14	25
Green Valley	1996	27	6	318	71	11	28
Green Valley	1999	--	--	--	--	5	10
Keomah	1994	106	31	--	--	38	22
Miami	1991	589	129	359	94	19	14
Miami	1995	224	71	93	37	20	12
Nine Eagles	1992	209	70	217	23	55	58
Prairie Rose	1994	496	72	1,105	293	17	17
Red Haw	1990	75	39	--	--	58	32
Red Haw	1997	71	32	11	9	42	36
Red Haw	2001	123	13	74	16	7	25
Rock Creek	1999	48	13	334	67	3	4
Swan	1990	758	153	79	36	54	68
Swan	1991	1,164	122	30	12	49	55
Swan	1992	1,083	88	9	2	22	53
Swan	1993	799	91	2,557	297	40	58
Swan	1994	575	103	1,847	312	17	29
Swan	1995	466	119	1,792	360	15	21
Swan	1996	802	98	1,053	326	9	8
Williamson	1991	180	37	372	73	8	3
Williamson	1997	391	114	550	175	22	16
Average		717	120	484	100	47	38

[1] Largemouth Bass > 5 inches

Crappie density was greatest at Swan Lake during 1993, 1994, 1995, and 1996 with an estimated 1,053 to 2,557 per acre. Crappie were nearly nonexistent at Red Haw (1990), Keomah, and Bobwhite Lakes. Biomass estimates were near 300 lbs per acre at Swan during 1993, 1994, 1995, 1996, and Prairie Rose during 1994. Average density and biomass estimates were 484 fish per acre and 100 lbs of crappie per acre.

Largemouth bass density was approximately 50 per acre at Red Haw Lake (1990), Nine Eagles Lake (1992), and Swan Lake (1990 and 1991). Greatest density occurred at Ahquabi Lake in 2001 at 231 per acre. Lowest density was 3 per acre, estimated at Rock Creek Lake. Greatest largemouth bass biomass was 117 lbs per acre and occurred at Lake Ahquabi during 2002, while lowest biomass of 4 lbs per acre occurred at Rock Creek Lake. Average largemouth bass density and biomass for the study lakes was 47 fish per acre and 38 lbs per acre.

Growth

Bluegill, largemouth bass, and crappie growth statistics were described using the Walford plot (Figure 1). Length at age *t* was plotted against length at age *t* + 1. The example in Figure 1 is for Lacey-Keosauqua bluegill with mean back-calculated lengths for age 1-7 of 2.60, 4.17, 5.28, 6.18, 7.40, 8.11 and 8.58 inches. Slope of the Walford line was 0.83 with an intercept of 1.95 inches and an R^2-value of 0.98. From this information the $L_{(MAX)}$-value was calculated at 11.5 inches. This value is where the growth equation intersects the Y=X line.

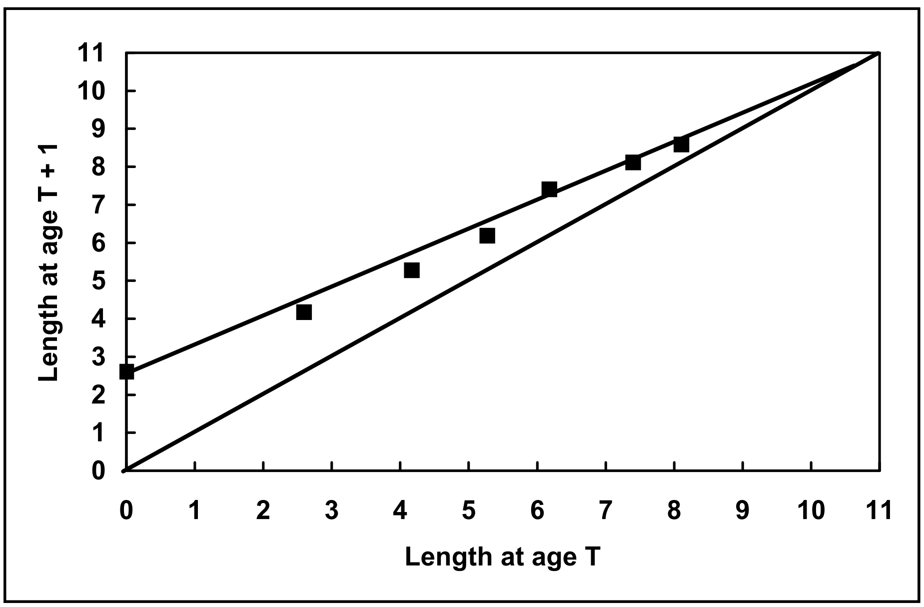

FIGURE 1.—Walford graph of bluegill growth at Lacey-Keosauqua Lake.

This process was used to calculate growth statistics for the target species at all study lakes (Table 4). Slope of growth curves for bluegills ranged from 0.44 at Williamson Pond to 0.83 at Lacey-Keosauqua. Length at maximum growth (L_{MAX}) for bluegills ranged from 6.4 inches at Williamson Pond to 11.5 inches at Lacey-Keosauqua, average for 23 study lakes was 8.5 inches.

Slope of growth curves for largemouth bass ranged from 0.50 at Yellow Smoke Lake to ≥0.85 at Keomah, Swan, Ahquabi, and Mariposa Lakes. The growth parameter, (L_{MAX}), ranged from 13.5 inches at Yellow Smoke Lake to > 25.0 inches at Green Valley, Mariposa, Ahquabi and Swan Lakes. Average L_{MAX} for largemouth bass at the study lakes was 21.0 inches.

TABLE 4.—Walford growth statistics for bluegills, largemouth bass and crappie where *B* is slope of the Walford graph and $L_{(MAX)}$ is the average asymptotic length (in) fish can attain.

	Bluegills		Largemouth Bass		Black Crappies		White Crappies	
Lake	*B*	(L_{MAX})	*B*	(L_{MAX})	*B*	(L_{MAX})	*B*	(L_{MAX})
Ahquabi	0.78	10.5	0.87	30.8	--		0.69	13.7
Anita	0.69	10	0.82	24.4	--	--	--	--
Anita, 2001	0.74	11	0.67	16.6	--	--	--	--
Bobwhite	0.69	7.8	0.73	17	--	--	--	--
Green Valley	0.55	7.9	0.83	25.2	0.59	9.5	--	--
Hawthorn	0.77	9.2	0.72	17.5	0.47	10.9	--	--
Iowa	0.64	8.2	0.77	21.9	--	--	0.59	10.6
Keomah	0.56	8.3	0.85	21.3	--	--	--	--
Lacey-Keosauqua	0.83	11.5	0.65	14.4	--	--	--	--
Mariposa	0.81	10.1	0.86	27.4	0.75	15.4	--	--
Miami	0.68	8.2	0.80	19.1	0.67	11.9		13.7
Nine Eagles	0.65	8.2	0.69	14.8	0.69	11.3	--	--
Pahoja	0.68	8.5	0.73	18.3	[a]	[a]	--	--
Pollmiller	0.74	11.2	0.82	17.2	--	--	--	--
Prairie Rose	0.59	8.2	0.81	22.8	0.67	10.5	--	--
Red Haw	0.70	9.8	0.73	15.5	0.62	11.4	--	--
Rock Creek	0.77	10.5	0.80	25.0	0.65	10.1	0.78	15.8
Slip Bluff	0.56	6.5	0.65	15.1	0.63	8.3	0.86	24.5
Smith	0.60	8.1	0.82	24.4	--	--	[a]	[a]
Swan 1991	0.74	10	0.92	24.3	0.55	11.2	--	--
Swan 1995	0.55	7.3	0.86	27.9				
Union Grove	0.74	8.9	0.84	22.5	0.52	8.6	--	--
Viking	0.70	7.9	0.76	20.9	[a]	[a]	--	--
Williamson Pond	0.44	6.4	0.72	22.7	0.48	8.8	[a]	[a]
Yellow Smoke	0.54	9.6	0.50	13.5	--	--	--	--

[a]Inadequate sample size.

Black crappie growth characteristics yielded slopes that ranged from 0.47 at Hawthorn Lake to 0.81 at Lake Anita; the average was 0.59. Length at maximum growth (L_{MAX}) ranged from 8.3 inches at Slip Bluff Lake to 15.4 inches at Lake Mariposa; average was 11.2 inches. Growth statistics were represented by only four white crappie populations (Table 4).

Condition

Body condition was determined for bluegill and largemouth bass at 23 study lakes, and crappie at 19 study lakes (Appendix A). Average W_r values for bluegills ranged from 81 at Mariposa Lake in 1996 to 125 at Yellow Smoke Lake in 1995. Standard deviations were about 13, but ranged from 6 to 25, while the average relative weight for bluegill was 101.

Body condition of largemouth bass ranged from 80 at Red Haw Lake in 1994 to 119 at Yellow Smoke in 1998. Average relative weight for largemouth bass was 99 with a standard deviation of 6 to 20.

Relative weight of black crappie ranged from 74 at Iowa Lake, 1999, to 115 at Smith Lake in 1995. Standard deviations of relative weight ranged from 5-25 with a median of 10. White crappie W_r 's ranged from 74 at Lake Ahquabi in 1997, to 116 at Smith Lake in 1997. Average W_r for black and white crappies was 95 and 92, respectively.

Size structure

Size structure of bluegill populations are shown in Appendix B. Relative stock density (RSD-stock: 3-6 inches) ranged from 0% at Red Haw Lake in 1995, to 100% at Yellow Smoke Lake in 1996, and Miami Lake in 1997. The average was 55% (SD = 23%). Quality sized bluegills (6-8 inches) ranged from 0% at Yellow Smoke Lake (1996), Viking Lake (1998), and Miami Lake (1997) to 93% at Rock Creek Lake in 1993. Average quality size was 39% (SD = 23%). Larger bluegills in the preferred category (8-10 inches) ranged from an RSD of 0% at many lakes to 87% at Red Haw, 1995. Relative stock density, preferred, was 5% for 23 study lakes.

Size structure of largemouth bass populations was more variable than that of bluegill populations. For example, RSD-stock (8-12 inches) ranged from 4% at Swan Lake (1990) and Green Valley Lake (1997) to 96% at Hawthorn Lake (1994) and Lacey-Keosauqua Lake (1993) (Appendix C). Overall average for this size class was 47% with a standard deviation of 24%. For intermediate largemouth bass, RSD-Quality (12-15 inches) ranged from 1% at Williamson Pond, 1991, to 90% at Yellow Smoke Lake, 1997. The average RSD values for these bass was 38% (SD = 19%). Bass larger than 15 inches had an RSD-preferred range of 0% for 20 samples to 71% for the population at Green Valley Lake, 1993. The average RSD-preferred for all lakes was 14% (SD = 14%).

Crappie size structure is shown in Appendix D. The RSD-stock (5-8 inches) ranged from 0% for several populations to 100% at Smith Lake (1992), Hawthorn Lake (1994), and Mariposa (1996). The average for this size group was 47% (SD = 29%). RSD-quality (8-10 inch) crappie ranged from 0% at Swan, 1993, Hawthorn, 1994, Smith Lake, 1992 and Mariposa, 1996 to 100% at Williamson Pond, 1997. The average RSD-quality was 44% (SD = 27%). Number of larger crappie in the RSD-preferred range (10-12 inches) varied from nonexistent in 64 samples to 96% at Red Haw Lake, 1995. Average and standard deviation for this length group of crappies were 9% and 16%, respectively.

Well-being Index and Model Development

An index of fish population well-being was developed and based upon three parameters: growth, body condition, and size structure. These indices were developed for bluegills, largemouth bass, and crappie (Table 5). Points for size structure were summed and divided by 3, so that maximum points awarded for size structure was 10. Maximum points for growth and body condition was 5 for each category. Scores for each of the parameters (size, growth and condition) were then summed, and the maximum possible point value was 20. This raw score was then divided by 4 to yield a final rating score of 1-5, one being poorest and five being best.

TABLE 5.—Criteria used to complete a well-being index for bluegill, largemouth bass, and crappie in Iowa lakes.

Growth: (L_{MAX}) values (in).					
Bluegill		Largemouth Bass		Crappie	
Value	Points	Value	Points	Value	Points
6-6.9	1	13-14.9	1	8-9.9	1
7-7.9	2	15-16.9	2	10-11.9	2
8-8.9	3	17-18.9	3	12-13.9	3
9-9.9	4	19-20.9	4	14-15.9	4
≥10	5	≥21	5	≥16	5
Body Condition: W_r -values					
Bluegill		Largemouth Bass		Crappie	
Value	Points	Value	Points	Value	Points
<93	1	<93	1	<85	1
93-95	2	93-95	2	96-95	2
96-99	3	96-99	3	96-100	3
100-109	4	100-109	4	101-110	4
>109	5	>109	5	>110	5
Bluegills size structure, RSD-values					
Stock (3-6)	Points	Quality (6-8)	Points	Preferred (8-10)	Points
<10	0	≤5	1	0	0
11-20	1	6-15	3	1	1
21-30	3	16-25	5	2	3
31-40	5	26-35	7	3	5
41-50	7	36-45	10	4	7
51-60	10	46-55	7	≥5	10
61-70	7	56-75	5		
71-80	5	76-95	3		
81-90	3	96-100	1		
91-100	1				
Largemouth bass size structure, RSD-values					
Stock (8-12)	Points	Quality (12-15)	Points	Preferred (15-20)	Points
0-15	0	0-5	1	0	0
16-25	1	6-15	3	1	1
26-35	3	16-25	5	2	3
36-45	5	26-35	7	3	5
46-55	7	36-45	10	4	7
56-65	10	46-55	7	≥5	10
66-75	7	56-75	5		
76-85	5	76-95	3		
86-95	3	96-100	1		
96-100	1				

TABLE 5.—Continued.

Crappie size structure, RSD-values

Stock (5-8)	Points	Quality (8-10)	Points	Preferred (10+)	Points
0-10	0	1-10	0	0-2	0
11-20	1	11-20	1	3-4	1
21-30	3	21-30	3	5-6	3
31-40	5	31-40	5	7-8	5
41-50	7	41-50	7	9-10	7
51-60	10	51-60	10	$\geq$11	10
61-70	7	61-70	7		
71-80	5	71-80	5		
81-90	3	81-90	3		
91-100	1	91-100	1		

An example of the mechanics of this system is provided by the 1992 data for Lake Anita bluegills. Average body condition was 94; thus 2 points were given. Measurement of growth (L_{MAX}) was 10 inches; thus, 5 points were given. RSD-values for stock, quality, and preferred categories were 64, 22, and 14; thus, points awarded were 7, 5 and 10, and the average was 7.33. Adding the latter to growth and body condition points yielded 14.33 points. The final rating was obtained by dividing the score by 4. Therefore, the well-being index of bluegills at Lake Anita in 1992 was 3.6; somewhat above average.

This system was then used to award points and ratings for all the populations at all lakes (Appendix E). Bluegill populations which were consistently over the mean of a 3.0 rating were Anita (pre-yellow bass), Hawthorn, Iowa, Lacey-Keosauqua, Prairie Rose, Red Haw (pre-carp), Swan (pre-carp), and Union Grove.

Largemouth bass populations with ratings consistently over 3.5 were Anita, Green Valley, Iowa, Keomah, Prairie Rose, Rock Creek, Smith, Swan, Union Grove, and Viking Lakes. One method of comparing these lakes was the graphic representation of the bluegill and largemouth bass ratings (Figure 2). Lake Anita rankings for bass and bluegill fell in the upper right quadrant (previous to yellow bass invasion), while Red Haw (pre-carp) rankings were in the lower right quadrant. Bluegill populations ranked low for Green Valley, Slip Bluff, and Red Haw (post-carp); however, bass populations were above average at Green Valley, but low at Slip Bluff and Red Haw Lakes. The remaining 16 study lake ratings for bass and bluegill were less well defined, with values plotted in at least two quadrants.

Ratings for crappie populations were more variable than those of largemouth bass and bluegill. Lake Anita, however, had consistently ranked over 3.0 in 1992-1996 and in 1998. Low crappie ratings were found in many populations particularly at Green Valley, Keomah, Miami, and Red Haw Lakes. Average black crappie rating was 2.1, while average white crappie rating was 2.0.

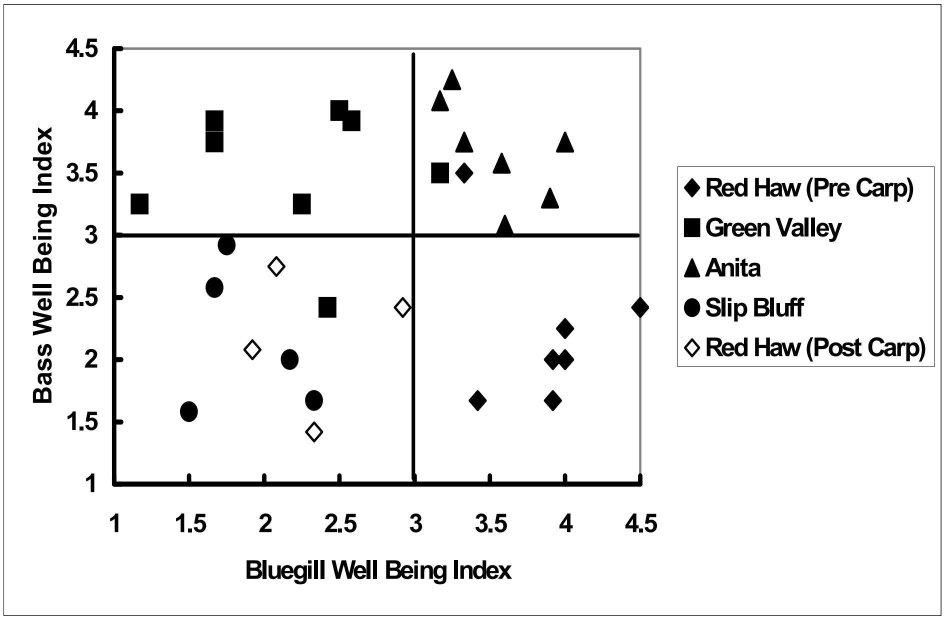

FIGURE 2.—Annual relationships between bluegill and largemouth bass well-being indices at four study lakes. A rating of one indicates a poor quality fishery and a rating of five suggests the fishery is in excellent condition.

Sport fish Harvest

Harvest statistics were available from 39 creel surveys conducted on 10 study lakes (Table 6). Annual fishing effort ranged from 52 hours/acre at Bobwhite Lake to an average of 281 hours/acre at Swan Lake, while the weighted average of angling effort for the 10 study lakes was 184 hours/acre.

TABLE 6.—A summary of sportfish harvest surveys conducted at 10 study lakes.

Lake	Number Surveys	Mean Effort (Hrs/Ac)	Bluegill *N*/Ac	Bass *N*/Ac	Crappie *N*/Ac	Harvest Fish/Hr
Ahquabi	6	233	98	<1	11	0.53
Anita	1	165	76	5	23	0.63
Bobwhite	1	52	23	<1	0	0.52
Green Valley	4	79	24	<1	28	0.77
Keomah	1	153	107	<1	12	0.98
Miami	2	150	119	1	101	1.51
Nine Eagles	6	80	43	4	6	0.62
Red Haw	7	203	201	4	45	1.45
Swan	10	281	53	2	75	0.58
Williamson Pond	1	65	8	0	17	0.60

Bluegill harvest ranged from 8 per acre at Williamson Pond to an average of 201 per acre at Red Haw Lake, with a weighted mean harvest of 85 per acre. Largemouth bass harvest was ≥ 4 per acre at Anita, Nine Eagles, and Red Haw, but ≤ 2 per acre at the remaining lakes. Crappie harvest ranged from 0 at Bobwhite Lake to 101 per acre at Miami Lake.

Fishing success, as measured in fish harvested per hour, was greatest at Miami Lake and averaged 1.51 over a two-year period. Red Haw produced the second greatest angling success at 1.45 fish per hour over a seven-year period. The number of fish harvested per hour of angling was lowest at Bob White Lake at 0.52 per hour followed by Ahquabi and Swan Lakes at 0.53 and 0.58. Lake Ahquabi was renovated and stocked with fish in 1986. This lake supported a newly developing fish community and most fish were released.

Lake Morphology, Water Quality, and Watersheds

Morphological characteristics of all study lakes were entered into a statewide database. Water quality statistics, obtained in 1979, 1990, and 2000 - 2005 for the lakes in this study, were also acquired and entered into these electronic files. Water quality parameters including Secchi disk depth, chlorophyll *a* and total phosphorous were incorporated into the Carlson Trophic State Index (TSI) (Carlson 1977; Appendix F).

Secchi disk depths ranged from 0.2 ft at Bobwhite Lake (2001) to 12.1 ft at Red Haw Lake (1990). Median and average Secchi disk depth for all lakes and years was 2.8 and 3.2 ft. Chlorophyll *a* concentration ranged from 2 mg/m^3 at Slip Bluff Lake (2000 and 2002) to 372 mg/m^3 at Swan Lake (2001). Median and average chlorophyll *a* concentration for the data set was 27 and 39 mg/m^3. Total phosphorus concentration ranged from 16 mg/m^3 at Slip Bluff (1979) to 752 mg/m^3 at Swan Lake (2000). Median and average phosphorus concentration for the data set was 92 and 137 mg/m^3. Carlson's TSI ranged from 48.6 at Red Haw Lake in 1990 to the more eutrophic value of 83.4 at Swan Lake in 2000. Median and average Carlson's TSI values were both 62.0 (SD = 6.1).

Analytical Comparisons and Discussion

The primary objective of the investigation was to define and delineate factors responsible for the well being of two important panfish in Iowa—bluegill and crappie. Factors examined were lake morphometry, lake water quality, watershed characteristics, angling, and predation. Correlation-regression was used to examine these complex data sets. Each of the statistical methods provided a unique analysis of the data sets; final analyses used regression, to yield a predictive endpoint.

<u>Panfish vs. Largemouth bass predation</u>

Correlations showed bluegill well-being indices were not associated with any largemouth bass parameters (Table 7). Lakes with greater proportions of large bluegill (>8 inches) showed significant negative correlations with largemouth bass, L_{MAX}, RSD-P (P = 15-20 inches), and largemouth bass well being indices. Bluegill populations which tended to have fish > 8 inches were associated with largemouth bass populations lacking fish in the 15-20 inch range (Table 7). Similarly, largemouth bass populations with slower growth were associated with populations with large bluegill. Lakes with consistent largemouth bass parameters associated with bluegill of high RSD-P (> 8 inches) were Red Haw, Lacey-Keosauqua, and Nine Eagles (Table 8).

TABLE 7.—Correlation coefficients (r) of bluegill well being indices and bluegill RSD-preferred versus largemouth bass population statistics.

	Largemouth Bass Parameters					
	W_r	RSD-S	RSD-Q	RSD-P	L_{MAX}	WBI
Bluegill WBI	0.0852	0.0179	-0.0300	-0.0109	0.0928	0.0560
Bluegill RSD-P	-0.2716	0.2062	-0.0253	-0.3283	-0.2145	-0.2694
Crappie WBI	0.1200	-0.3657	0.3325	0.2832	0.2185	0.1510
Crappie RSD-P	-0.5354	-0.1399	0.3649	-0.1391	0.0540	-0.2625

Correlations between crappie and largemouth bass population parameters are shown in Table 7. Crappie well-being indices were negatively associated only with largemouth bass RSD-S (8-12 inches). However, large crappie (> 10 inches) were significantly and positively correlated to largemouth bass quality, and negatively correlated to largemouth bass body condition.

TABLE 8.—Lakes with largemouth bass characteristics associated with bluegill having high RSD-P (> 8 inches)

Low bass RSD-P	Low bass growth	Low bass well being index
Lacey-Keosauqua	Yellow Smoke	Lacey-Keosauqua
Red Haw	Lacey-Keosauqua	Nine Eagles
Nine Eagles	Nine Eagles	Red Haw

Lake Morphometry and Watershed

Bluegill well-being indices were not correlated with biotic or abiotic variables. However, lakes with a large proportion of large bluegill (RSD-P, i.e., those greater than 8 inches), had positive, significant correlations with mean and maximum depths (Table 8). The greater proportion of larger bluegills was found in the lakes with the steeper lake basin slopes. Lakes that had characteristics conducive to high bluegill well-being indices and high RSD-P values for bluegill most often were characterized by high mean depth, high maximum depth, and high mean basin slope (Table 9). Lakes with consistent bluegill populations of high RSD-P (> 8 in) were Viking, Red Haw, and Nine Eagles (Table 10).

There were no significant correlations between crappie well-being indices or preferred size and lake morphometry or lake acreage. There was, however, a negative relationship with larger crappie (> 10 inches) and watershed ratio (Table 9). Largemouth bass well-being indices were significantly and positively associated with lake size, but negatively correlated with mean depth, maximum depth, and mean basin slope (Table 9). Largemouth bass populations with proportionately more fish over 15 inches (RSD-P) were also negatively correlated with mean depth, maximum depth, and mean basin slope. Shallow lakes with a concave basin shape tended to have bass populations with proportionally more bass greater than 15 inches. These lakes included Smith, Union

Grove, Slip Bluff, Green Valley, and Keomah Lakes.

TABLE 9.—Correlation coefficients (r) between bluegill, crappie, and largemouth bass well being indices (WBI), relative stock density-preferred (RSD-P), and lake morphometry and watershed characteristics. MND is mean depth in feet, MXD is maximum depth in feet, RELD is relative depth, MBS is mean basin slope, WSR is watershed area:lake area ratio, and WSS is watershed size in acres.

	MND	MXD	RELD	MBS	WSR	WSS
BLG WBI	0.0893	0.1573	-0.0434	-0.0447	0.0510	0.0577
BLG RSD-P	0.319*	0.3374*	0.0157	0.1304	-0.1338	-0.0756
CRA WBI	0.1256	0.1834	-0.1821	-0.1848	-0.1466	-0.1093
CRA RSD-P	0.1940	0.1445	0.1008	0.2117	-0.314*	-0.2337
LMB WBI	-0.45**	-0.3075*	-0.63**	-0.72**	0.1921	0.335*
LMB-RSD-P	-0.49**	-0.3673*	-0.60**	-0.55**	0.0885	0.49**

*Significant at the 0.05 level

**Significant at the 0.01 level

TABLE 10.—Lakes with physical characteristics associated with high bluegill well-being indices and high RSD-P values.

Highest Mean Depth	Greatest Maximum	Lowest Volume Development	Highest Mean Basin Slope
Viking	Viking	Viking	Slip Bluff
Red Haw	Red Haw	Pahoja	Lacey-Keosauqua
Nine Eagles	Nine Eagles	Red Haw	Red Haw
Anita	Hawthorn	Bob White	Viking
Lacey-Keosauqua	Iowa	Prairie Rose	Nine Eagles

Water Quality

Bluegill of proportionately large size (>8 in) were adversely affected by eutrophication. For example, there was a significant, negative correlation with phosphorus (r = -0.25). Lakes with better water quality in terms of lower turbidity included Red Haw, Nine Eagles, Yellow Smoke, and Lacey-Keosauqua Lakes. Lowest phosphorus concentrations were found at Yellow Smoke, Red Haw, Slip Bluff, Nine Eagles, and Lacey-Keosauqua Lakes.

Crappie populations were not adversely affected by turbidity or chlorophyll *a*; however, crappie well-being indices were negatively correlated with total phosphorus concentrations (r = –0.19). The five lakes with highest phosphorus levels were Swan, Pahoja, Bob White, Mariposa, and Williamson Lakes.

Largemouth bass well-being indices were positively associated with more eutrophic conditions. Likewise, lakes with higher proportions of largemouth bass larger than 15 inches (RSD-P) were more eutrophic. For example, correlation coefficients between bass well being indices were –0.56, +0.42, and +0.38 for Secchi disc depth, chlorophyll *a* and phosphorus, respectively. *R*-values for

RSD-P were –0.51, +0.46, and +0.38 when correlated to the same water quality parameters.

Multiple Regression

Lakes with a preponderance of large bluegill (> 8 inches) were best described by the multiple regression model:

BLGRSD-P= 12.81 – 0.104* LMB W_r + 0.125*MAXD – 0.00012*PHOS+ 0.008*WSRATIO – 0.062*LMBRSD-P

where the dependent variable (BLGRSD-P) was the proportion of bluegill greater than 8 inches, and the independent variables were

LMB W_r = largemouth bass relative body condition
MAXD = maximum depth, in feet
PHOS = total phosphorus concentration
WSRATIO = watershed area to lake area ratio
LMBRSD-P = percent of largemouth bass greater than 15 inches

This model had an r-value of 0.42; thus, these variables accounted for 18% of the variability in the proportion of large bluegill found in the various populations. Maximum depth was the most influential metric in this model. Deeper lakes with lower phosphorus levels were conducive to large bluegill. Poorly structured bass populations, dominated by small fish and poor body condition, were associated with bluegill populations having more fish over 8 in.

The same method was followed for bluegill well-being indices. The same biotic and abiotic variables influenced the well-being of bluegill; however, the multiple regression was not significant.

Lakes with a greater proportion of large crappie (RSD-P), (i.e., greater than 8 in) were best characterized by

CRARSD-P = 83.27 – 0.002*PHOS – 0.011 WSRATIO - 0.759*LMB W_r – 0.076*LMBRSD-P

where the dependent variable CRARSD-P was the proportion of crappie greater than 8 inches, and the independent variables were

PHOS = total phosphorus concentration
WSRATIO = watershed:lake area ratio
LMB W_r = largemouth bass relative body condition
LMBRSD-P = percent of largemouth bass greater than 15 in.

The multiple regression model had a significant *r*-value of 0.54, thus the model accounted for 30% of the variability in crappie RSD-P. Lakes with large crappie were characterized by lakes with low phosphorus, bass with lower than average body condition and a small proportion of large largemouth bass. Crappie well-being indices had similar responses to biotic and abiotic variables, but the regression values were not significant.

AGNPS and Water Quality

Bluegill and crappie populations were adversely affected by eutrophic conditions of study lakes. Furthermore, larger watersheds and larger lake:watershed area ratios showed adverse affects upon bluegill and crappie populations. The regimented study of the watershed using the Agricultural Nonpoint Source (AGNPS) model better described the relationships between watersheds and water quality, and thus water quality and bluegill and crappie populations.

Significant correlations were found to exist between water quality measurements taken by Bachmann (1980, 1991) and Downing (2000) and the predicted nutrient loading as estimated by the AGNPS model (Table 10). Estimated sediment, nitrogen and phosphorus loading were all positively correlated to watershed size, watershed/lake area ratio, Secchi disk depths, and phosphorus concentrations found in lakes. Conversely, the AGNPS loading estimates were negatively correlated to primary production as measured by chlorophyll *a*. It is readily apparent that watershed size, ratio of lake area to watershed area, land use, slope and ground cover are vitally important to nutrient loading, which is important to lake water quality, which in turn is related to the well-being of bluegill and crappie populations.

TABLE 11.—Correlation coefficients between AGNPS loading predictions, based on a 2-inch rain, and water quality as measured by Bachmann (1980; 1991) and Downing (2000). All relationships are significant ($P \leq 0.05$).

	Water quality parameters				
AGNPS parameters	Watershed size	Watershed/Lake ratio	Secchi	Chlorophyll (*a*)	Phosphorus
Sediment tons/acre	0.284	0.398	0.687	-0.349	0.498
Sediment N lbs/acre	0.438	0.625	0.599	-0.349	0.453
Sediment P lbs/acre	0.439	0.626	0.598	-0.350	0.453

Angler Harvest

The affect of largemouth bass harvest on well being indices for largemouth bass was negative and accounted for 10% ($P > 0.05$) of the variability in size structure, growth, and body condition. The greater number of largemouth bass harvested per acre yielded lower well-being indices for largemouth bass, and indicated anglers can have a negative affect upon these populations.

Greater fishing effort was associated with higher well-being indices of bluegill. Conversely, low fishing effort was associated with lower well-being indices. Correlation of bluegill well-being indices and fishing effort was 0.59; thus 35% of the variability in bluegill well-being indices was accounted for by fishing effort. However, bluegill harvest accounted for only 4% of the variability in bluegill well-being; whereas, crappie harvest accounted for 5% of the variability in crappie well-being. These correlations were probably not cause-and-effect related and the following two questions remain: Is low harvest the result of unappealing fish populations as viewed by the angler? Or are fish populations unappealing because anglers have over-harvested the species? The important fact is panfish populations were not overexploited in the study lakes, and higher harvests were associated with higher well-being indices. A good example was at Red Haw Lake where an average of 203 hrs/acre were expended by anglers targeting bluegill, yet well-being indices for bluegill were in the top 25% of all lakes studied. The opposite was true at Williamson Pond where 65 hrs/acre of effort were expended and bluegill well-being indices were among the lowest at 1.50.

Major factors influencing panfish populations included lake basin shape, watershed characteristics and lake water quality. The influence of predation by largemouth bass and role of angler harvest were not demonstrated in this study. It appears that high angler exploitation can have a negative affect on the size structure of largemouth bass. Lake basin shape is the most important factor in establishing the goodness or poorness of largemouth bass and panfish populations. Watershed characteristics are also important because lake morphology and water quality are greatly influenced by watershed. This investigation has shown predation of largemouth bass on panfish, and harvest of panfish by anglers play a relatively small role in the well-being of crappie and bluegill populations in Iowa lakes. The quality of these fisheries is much more closely linked to environmental factors such as lake basin shape, hydrological factors associated with the watershed and lake water quality.

Recommendations and Conclusions

1. Lakes with proportionately larger bluegill were associated with largemouth bass populations dominated by fish smaller than 15 in. This indicated bass minimum size limits, although required to protect large largemouth bass, are not justified as a tool to enhance bluegill populations. Other factors have a much greater influence on quality and relative size of bluegill populations.
2. The relationship between anglers and largemouth bass populations showed high harvest was correlated with poor size structure. Largemouth bass harvest regulations are justified if the objective is to provide fishing for larger bass.
3. A positive relationship existed between angler harvest and well-being indices calculated for bluegill and crappie populations. Lakes that produced the highest bluegill harvest were those lakes with the highest quality bluegill populations. This indicated panfish harvest regulations, either by size or number, are not justified. In fact, panfish harvest should be encouraged, particularly at lakes with poor panfish size structure, growth, and body condition.
4. Watershed characteristics and lake basin shape influence the quality of the fish community and, thus, the quality of fishing. Thus, lake site selection is critical and will determine the quality of water, fish and recreation the lake will support. Bluegill, the most important sport fish in Iowa's constructed lakes, is positively influenced by low watershed:lake area ratios and steep basin slopes. Mean depth and maximum depth are also positively correlated to quality of bluegill populations. Watershed modeling showed sediment and nutrient loading has a significant impact on the well-being of panfish populations. The lower the sediment and nutrient runoff from the watershed the better the panfish angling; therefore, these factors must be addressed as part of lake protection and restoration and used in selection of sites for lake construction.
5. Lakes that have already been constructed can benefit from lake deepening and reduction of soil and nutrient erosion in the watershed. Technology is available to predict the reduction in sediment and nutrient loading from watershed erosion control work and implementation of best management practices on land in the lake watershed. These benefits should be compared to the cost required to implement these practices. These costs and associated benefits should then be considered during prioritization of lake improvement efforts. Even if lakes are not candidates for rehabilitation, the well-being of fish populations can be assessed relative to physical characteristics of the lake and its watershed. Lakes containing undesirable panfish populations should be examined to determine potential for improvement. Fish management can then target problem species and those species best suited for a particular lake.
6. This investigation should be extended to expand the data sets and provide greater confidence in defining those factors that influence the quality of water, habitat, biota and recreation associated with constructed lakes. This database will

include the plant community. The well-being indices developed in this study should be tested at several other lakes with long-term management history. Emphasis should be placed on economically expanding the data available on important lakes and watersheds of the state. Analysis by AGNPS is time consuming and expensive. Greater use of Geographical Information System (GIS) should be made in conjunction with satellite imagery and recently developed watershed based models to analyze for nonpoint sediment and nutrient loading.

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Appendix A.—Average W_r -values and standard deviations (SD) for bluegills, largemouth bass, and crappies sampled from 23 study lakes.

		Bluegill		Largemouth Bass		Black Crappie		White Crappie	
Lake	Year	W_r	SD	W_r	SD	W_r	SD	W_r	SD
Ahquabi	1997	99	7	84	11			74	8
Ahquabi	1998	95	15	95	15			91	7
Ahquabi	1999	102	19	92	13			98	11
Ahquabi	2000	105	20	93	9				
Ahquabi	2001	94	13	85	10	95	10	102	6
Ahquabi	2002	91	14	85	13				
Anita	1992	94	16	93	12	98	10	91	7
Anita	1993	105	15	97	10	88	8		
Anita	1994	110	12	105	12	105	12		
Anita	1995	109	15	99	11	94	13		
Anita	1996	106	15	102	12	91	13		
Anita	1997	105	15	101	12	94	10	95	7
Anita	1998	104	15	81	11	101	14		
Anita	2001	93	10	89	14				
Bob White	1992	86	8	104	10				
Bob White	1993	95	15	102	8				
Bob White	1994	104	10	103	10			98	6
Bob White	1995	98	8	98	7				
Bob White	1996	86	9	90	10			86	9
Bob White	1997	97	12	91	10				
Bob White	1998	90	14	95	8			84	11
Bob White	1999	92	13	103	17			82	9
Bob White	2000	106	11	105	10			93	6
Bob White	2001	98	19	104	11			89	13
Bob White	2002	94	10	102	14			79	14
Green Valley	1993	121	15	112	10	98	8		
Green Valley	1994	96	19	107	13	89	12		
Green Valley	1995	86	11	101	13	97	8	97	11
Green Valley	1996	99	8	92	11	97	8	93	6
Green Valley	1997	101	10	100	9	97	9	95	10
Green Valley	1998	110	16	106	10	99	9	94	11
Green Valley	1999	120	14	106	6	101	7	94	7
Green Valley	2000	94	13	96	8	83	8	86	11
Hawthorn	1992	107	11	102	9	97	8		
Hawthorn	1993	109	10	97	10				
Hawthorn	1994	108	12	107	8	91	4	75	29
Hawthorn	1995	111	14	117	14	107	10		
Hawthorn	1996	101	6	97	9	93	4		
Hawthorn	1997	105	12	97	8	92	4		
Hawthorn	1998	104	11	97	9	98	9	101	11
Iowa	1992	107	15	105	11	99	11	100	11
Iowa	1993	98	9	100	9	96	7		
Iowa	1994	95	9	104	8	93	10		
Iowa	1995	100	11	101	11	98	8	96	8
Iowa	1996	99	14	98	9	94	9		
Iowa	1997	96	10	95	7	92	8		
Iowa	1998	105	11	107	8	99	7		
Iowa	1999	87	10	100	9	74	5	102	8
Keomah	1993	102	10	94	9				

Appendix A.—Continued		Bluegill		Largemouth Bass		Black Crappie		White Crappie	
Lake	Year	W_r	SD	W_r	SD	W_r	SD	W_r	SD
Keomah	1994	95	10	98	8	97	12		
Keomah	1995	104	10	103	11	81	7	94	3
Keomah	1996	94	8	95	6	88	14		
Keomah	1997	95	6	101	8				
Keomah	1998	103	14	98	9	85	4		
Keomah	1999	104	15	99	8				
Keomah	2000	98	12	102	9				
Keomah	2002	97	13	99	9				
Keomah	1992	98	9	89	8				
Lacey-Keosauqua	1993	112	12	89	6				
Lacey-Keosauqua	1994	107	6	89	7				
Lacey-Keosauqua	1995	100	9	90	6				
Lacey-Keosauqua	1992	113	13	110	9				
Mariposa	1993	96	13	99	9				
Mariposa	1994			95	13	104	23	100	21
Mariposa	1995	99	25	104	11	90	16		
Mariposa	1996	81	24	95	12	58	25		
Mariposa	1997	88	11	87	12	88	8		
Mariposa	1998	83	20	105	20	79	6		
Mariposa	1990	99	13	96	10	94	9	92	8
Miami	1991	91	10	99	11	93	9	88	10
Miami	1992	91	12	100	11	98	9	94	11
Miami	1993	92	16	90	10	90	5	84	7
Miami	1994	105	13	93	9				
Miami	1995	99	11	114	9	91	9	94	10
Miami	1996	93	9	94	8	96	8	87	4
Miami	1997	97	10	93	7	95	6	95	7
Miami	1998	105	11	94	8	101	13	97	8
Miami	1999	106	14	97	9			97	9
Miami	2000	100	12	97					
Miami	2001	89	21	102	10	96	18	93	15
Miami	2002	92	11	97	10	91	8	90	6
Miami	1989	94	10	91	10	81	13		
Nine Eagles	1990	89	15	91	10	86	10		
Nine Eagles	1991	84	8	93	9	89	12		
Nine Eagles	1993	102	13	94	12	89	10		
Nine Eagles	1994			87	7				
Nine Eagles	1995	92	12	84	10	81	7	83	20
Nine Eagles	1996	93	9	87	8	87	7		
Nine Eagles	1997	93	10	89	10				
Nine Eagles	1998	91	15	90	12	95	12		
Nine Eagles	1999	92	12	94	17				
Nine Eagles	2000	91	6	95	10				
Nine Eagles	1992	111	9	112	15	104	5		
Pahoja	1993	115	8	115	11	108	8		
Pahoja	1994	104	6	109	10	108	5		
Pahoja	1992	97	13	101	6				
Polmiller	1993	95	12	97	7				
Polmiller	1994	91	13	98	8				
Polmiller	1995	100	12	98	8				
Polmiller	1996	103	18	100	15				
Polmiller	1997	94	9	99	8				
Polmiller	1999	97	10	100	11				
Polmiller	1994	106	16	103	10	90	10		

Appendix A.—Continued		Bluegill		Largemouth Bass		Black Crappie		White Crappie	
Lake	Year	W_r	SD	W_r	SD	W_r	SD	W_r	SD
Prairie Rose	1996	107	15	108	14	101	9		
Prairie Rose	1997	103	14	107	7	96	10		
Prairie Rose	1998	90	12	96	8	88	7		
Prairie Rose	1990	106	14	94	11				
Red Haw	1991	111	12	86	8				
Red Haw	1992	108	11	94	11	104	16		
Red Haw	1993	102	13	98	8	103	9		
Red Haw	1994	100	11	80	9				
Red Haw	1996	104	11	86	10				
Red Haw	1997	106	14	85	8	88	10		
Red Haw	1998	94	13	94	8	97	6		
Red Haw	1999	87	12	85	11				
Red Haw	2000	87	10	88	9	88	5		
Red Haw	2001	96	13	84	10	87	6		
Red Haw	2002								
Red Haw	1999	104	12	104	12	109	13	100	15
Rock Creek	1992	94	14	92	8	100	10	89	12
Slip Bluff	1993	94	12	93	10	84	6	77	7
Slip Bluff	1994	90	9	92	11	81	7	87	12
Slip Bluff	1996	86	9	90	10	85	6	80	9
Slip Bluff	1997	89	11	94	12	90	7		
Slip Bluff	1992	120	10	104	12			97	10
Smith	1993	104	7	103	10			94	6
Smith	1994	109	12	107	7				
Smith	1995	113	15	111	8	114	13	109	14
Smith	1996	109	15	108	12			97	5
Smith	1997	112	17	106	6	115	11	116	11
Smith	1998	120	9	102	8	101	8	96	7
Smith	1989	102	14	92	15	114	13		
Swan	1990	95	13	93	13	108	9		
Swan	1991	107	15	109	15	108	14		
Swan	1992	92	16	108	14	89	11		
Swan	1993	103	17	104	17	99	16		
Swan	1994	114	19	96	14	91	9		
Swan	1995	106	15	91	15	105	13		
Swan	1996	110	15	110	11				
Swan	1993	101	10	107	8	105	6		
Union Grove	1994	98	10	103	8	94	6		
Union Grove	1995	110	17	114	12	99	19		
Union Grove	1996	115	15	111	11			105	8
Union Grove	1997	102	14	114	8	102	6		
Union Grove	1998	114	14	109	9	97	8		
Union Grove	1999	99	11	100	9	97	5	91	8
Union Grove	1992	112	21	100	9	98	13	108	20
Viking	1993	115	22	100	12	98	10		
Viking	1994	106	19	94	8	85	8		
Viking	1995	113	14	106	10			105	11
Viking	1996	103	16	98	12	92	12		
Viking	1997	114	12	108	10			98	12
Viking	1998	88	10	95	6	83	8		
Viking	1991	93	10	87	12	81	10	84	10
Williamson Pond	1992	103	10	91	7	94	10	91	8
Williamson Pond	1994	106	19	103	14			85	9
Williamson Pond	1995	92	10	97	12	85	12	82	6

Appendix A.—Continued		Bluegill		Largemouth Bass		Black Crappie		White Crappie	
Lake	Year	W_r	SD	W_r	SD	W_r	SD	W_r	SD
Williamson Pond	1996	96	9	97	9	94	5	87	5
Williamson Pond	1997	98	15	97	8	88	23	87	5
Williamson Pond	1998	99	14			100	15		
Williamson Pond	1999	98	15	102	12				
Williamson Pond	2000	104	10	97	8	100	10	88	7
Williamson Pond	2002	112	9	113	9	101	7	91	6
Williamson Pond	1992	106	13	106	14				
Yellow Smoke	1993	93	20	104	6				
Yellow Smoke	1994	102	17	114	14				
Yellow Smoke	1995	125	18	117	15				
Yellow Smoke	1996	114	22	101	11				
Yellow Smoke	1997	100	9	109	8				
Yellow Smoke	1998	115	11	119	13				
Yellow Smoke	1999	103	12	107	11	112	9		
Yellow Smoke	2000	114	16	102	14				

Appendix B.—Relative stock density (RSD) of bluegills sampled from 23 lakes using three size classes.

Lake	Year	RSD-Stock (3-6 in)	RSD-Quality (6-8 in)	RSD-Preferred (8-10 in)
Ahquabi	1997	44	44	12
Ahquabi	1998	72	26	0
Ahquabi	1999	58	42	0
Ahquabi	2000	83	17	0
Ahquabi	2001	58	33	9
Ahquabi	2002	81	17	2
Anita	1992	64	22	14
Anita	1993	73	20	8
Anita	1994	80	14	6
Anita	1995	26	72	2
Anita	1996	80	18	2
Anita	1997	81	13	6
Anita	1998	64	22	14
Anita	2001	35	59	6
Bob White	1992	25	75	0
Bob White	1993	47	53	0
Bob White	1994	39	61	0
Bob White	1995	36	61	3
Bob White	1996	29	70	1
Bob White	1997	60	40	0
Bob White	1998	42	57	1
Bob White	1999	58	42	0
Bob White	2000	81	19	0
Bob White	2001	85	15	0
Bob White	2002	81	19	0
Green Valley	1993	41	59	0
Green Valley	1994	14	85	1
Green Valley	1995	37	62	1
Green Valley	1996	41	59	0
Green Valley	1997	56	44	0
Green Valley	1998	36	62	2
Green Valley	1999	78	22	0
Green Valley	2000	96	4	0

Appendix B.—Continued.

Lake	Year	RSD-Stock (3-6 in)	RSD-Quality(6-8 in)	RSD-Preferred (8-10 in)
Hawthorn	1992	52	45	3
Hawthorn	1993	54	41	5
Hawthorn	1994	20	24	56
Hawthorn	1995	66	10	24
Hawthorn	1996	41	54	5
Hawthorn	1997	31	63	6
Hawthorn	1998	40	54	6
Iowa	1992	51	44	5
Iowa	1993	45	55	0
Iowa	1994	60	36	4
Iowa	1995	22	65	14
Iowa	1996	49	45	6
Iowa	1997	33	64	2
Iowa	1998	78	22	0
Iowa	1999	35	64	1
Keomah	1993	57	38	6
Keomah	1994	9	51	40
Keomah	1995	92	4	4
Keomah	1996	68	31	1
Keomah	1997	26	74	0
Keomah	1998	13	87	0
Keomah	1999	70	30	0
Keomah	2000	75	25	0
Keomah	2002	33	24	42
Lacey-Keosauqua	1992	53	38	9
Lacey-Keosauqua	1993	72	15	13
Lacey-Keosauqua	1994	69	31	0
Lacey-Keosauqua	1995	76	31	0
Mariposa	1992	64	36	0
Mariposa	1993	33	67	0
Mariposa	1994	80	20	0
Mariposa	1995	25	74	1
Mariposa	1996	43	57	0
Mariposa	1997	53	47	0
Mariposa	1998	60	40	0
Miami	1990	27	71	2
Miami	1991	6	90	4
Miami	1992	39	59	2
Miami	1993	78	22	0
Miami	1994	67	33	0
Miami	1995	10	76	14
Miami	1996	93	7	0
Miami	1997	100	0	0
Miami	1998	75	25	0
Miami	1999	78	22	0
Miami	2000	81	19	0
Miami	2001	35	65	0
Miami	2002	37	57	6
Nine Eagles	1989	37	33	30
Nine Eagles	1990	59	18	23
Nine Eagles	1991	68	28	4
Nine Eagles	1993	56	19	25
Nine Eagles	1995	71	26	3
Nine Eagles	1996	72	28	0

Appendix B.—Continued.

Lake	Year	RSD-Stock (3-6 in)	RSD-Quality(6-8 in)	RSD-Preferred (8-10 in)
Nine Eagles	1997	81	19	0
Nine Eagles	1998	25	69	6
Nine Eagles	1999	27	67	6
Nine Eagles	2000	34	59	7
Pahoja	1992	62	38	0
Pahoja	1993	32	58	10
Pahoja	1994	91	9	0
Pahoja	1997	74	26	0
Polmiller	1994	89	11	0
Polmiller	1995	64	34	2
Polmiller	1996	92	5	3
Polmiller	1997	94	6	0
Polmiller	1999	67	31	2
Prairie Rose	1994	59	39	2
Prairie Rose	1996	61	39	0
Prairie Rose	1997	55	45	0
Prairie Rose	1998	64	36	0
Red Haw	1990	54	7	39
Red Haw	1991	47	37	16
Red Haw	1992	41	48	11
Red Haw	1993	88	8	5
Red Haw	1994	72	24	4
Red Haw	1995	0	12	87
Red Haw	1996	61	28	11
Red Haw	1997	98	2	0
Red Haw	1998	85	14	1
Red Haw	1999	82	18	0
Red Haw	2000	57	43	0
Red Haw	2001	77	23	0
Red Haw	2002			
Rock Creek	1999	14	93	3
Slip Bluff	1992	43	54	3
Slip Bluff	1993	41	59	0
Slip Bluff	1994	48	52	0
Slip Bluff	1996	57	43	0
Slip Bluff	1997	45	55	0
Smith	1992	82	18	0
Smith	1993	43	57	0
Smith	1994	17	83	0
Smith	1995	71	29	0
Smith	1996	48	48	3
Smith	1997	58	38	4
Smith	1998	35	65	0
Swan	1989	33	66	1
Swan	1990	49	46	5
Swan	1991	54	30	16
Swan	1992	46	37	18
Swan	1993	59	35	6
Swan	1994	64	36	0
Swan	1995	26	72	2
Swan	1996	37	60	3
Union Grove	1993	57	43	0
Union Grove	1994	17	80	3
Union Grove	1995	39	44	17

Appendix B.—Continued.

Lake	Year	RSD-Stock (3-6 in)	RSD-Quality(6-8 in)	RSD-Preferred (8-10 in)
Union Grove	1996	53	28	20
Union Grove	1997	44	41	15
Union Grove	1998	48	6	9
Union Grove	1999	44	50	6
Viking	1992	67	38	0
Viking	1993	46	52	2
Viking	1994	64	32	4
Viking	1995	40	56	4
Viking	1996	72	22	6
Viking	1997	59	39	2
Viking	1998	38	0	8
Williamson Pond	1991	17	83	0
Williamson Pond	1992	35	65	0
Williamson Pond	1994	51	47	2
Williamson Pond	1995	14	80	6
Williamson Pond	1996	9	86	5
Williamson Pond	1997	51	42	8
Williamson Pond	1998	25	3	6
Williamson Pond	1999	58	40	2
Williamson Pond	2000	18	80	2
Williamson Pond	2002	43	43	14
Yellow Smoke	1992	56	34	10
Yellow Smoke	1993	84	10	6
Yellow Smoke	1994	82	18	0
Yellow Smoke	1995	92	8	0
Yellow Smoke	1996	100	0	0
Yellow Smoke	1997	80	17	3
Yellow Smoke	1998	98	2	0
Yellow Smoke	1999	79	19	2
Yellow Smoke	2000	98	2	0

Appendix C.—Relative stock density (RSD) of largemouth bass sampled from 23 study lakes using three size classes.

Lake	Year	RSD-Stock (8-12 in)	RSD-Quality (12-15 in)	RSD-Preferred (15-20 in)
Ahquabi	1997	77	15	8
Ahquabi	1998	78	17	5
Ahquabi	1999	83	13	4
Ahquabi	2000	91	8	1
Ahquabi	2001	74	26	0
Ahquabi	2002	79	21	0
Anita	1992	20	60	20
Anita	1993	11	73	16
Anita	1994	24	51	25
Anita	1995	35	34	30
Anita	1996	22	50	28
Anita	1997	22	61	17
Anita	1998	46	39	15
Anita	2001	16	60	24
Bob White	1992	59	33	8
Bob White	1993	43	53	4
Bob White	1994	30	59	11
Bob White	1995	18	64	18

Appendix C.—Continued.

Lake	Year	RSD-Stock (8-12 in)	RSD-Quality (12-15 in)	RSD-Preferred (15-20 in)
Bob White	1996	18	56	26
Bob White	1997	27	54	20
Bob White	1998	17	62	22
Bob White	1999	25	50	25
Bob White	2000	18	41	41
Bob White	2001	23	57	20
Bob White	2002	29	25	46
Green Valley	1993	18	54	28
Green Valley	1994	22	48	30
Green Valley	1995	29	46	26
Green Valley	1996	22	41	38
Green Valley	1997	4	69	27
Green Valley	1998	6	54	39
Green Valley	1999	13	39	48
Green Valley	2000	10	19	71
Hawthorn	1992	66	23	11
Hawthorn	1993	53	34	13
Hawthorn	1994	96	4	0
Hawthorn	1995	78	20	2
Hawthorn	1996	89	8	3
Hawthorn	1997	81	9	11
Hawthorn	1998	44	52	3
Iowa	1992	48	12	40
Iowa	1993	63	25	12
Iowa	1994	65	30	5
Iowa	1995	22	46	32
Iowa	1996	53	26	22
Iowa	1997	59	40	1
Iowa	1998	54	43	4
Iowa	1999	19	37	44
Keomah	1993	31	49	21
Keomah	1994	39	50	11
Keomah	1995	78	16	6
Keomah	1996	77	19	4
Keomah	1997	82	18	0
Keomah	1998	13	87	0
Keomah	1999	22	59	19
Keomah	2000	37	27	36
Keomah	2002	55	35	10
Lacey-Keosauqua	1992	82	18	0
Lacey-Keosauqua	1993	96	4	0
Lacey-Keosauqua	1994	63	37	0
Lacey-Keosauqua	1995	57	43	0
Mariposa	1992	87	9	4
Mariposa	1993	27	47	26
Mariposa	1994	20	69	11
Mariposa	1995	24	30	46
Mariposa	1996	30	33	38
Mariposa	1997	46	26	29
Mariposa	1998	36	25	39
Miami	1990	77	10	13
Miami	1991	73	24	3
Miami	1992	70	28	2
Miami	1993	81	18	1

Appendix C.—Continued.

Lake	Year	RSD-Stock (8-12 in)	RSD-Quality (12-15 in)	RSD-Preferred (15-20 in)
Miami	1994	71	26	3
Miami	1995	35	57	8
Miami	1996	46	48	6
Miami	1997	62	30	8
Miami	1998	38	52	10
Miami	1999	36	54	10
Miami	2000	59	28	16
Miami	2001	55	41	5
Miami	2002	64	35	1
Nine Eagles	1989	46	52	2
Nine Eagles	1990	61	39	0
Nine Eagles	1991	45	50	5
Nine Eagles	1996	43	57	0
Nine Eagles	1997	59	38	3
Nine Eagles	1998	79	21	0
Nine Eagles	1999	85	12	3
Nine Eagles	2000	93	7	0
Pahoja	1992	38	40	22
Pahoja	1993	55	25	21
Pahoja	1994	75	23	2
Pahoja	1997	48	49	4
Polmiller	1992	59	41	0
Polmiller	1993	46	52	2
Polmiller	1994	43	55	2
Polmiller	1995	43	55	2
Polmiller	1996	69	30	2
Polmiller	1997	46	54	0
Polmiller	1999	26	57	17
Prairie Rose	1994	67	14	18
Prairie Rose	1996	34	43	23
Prairie Rose	1997	15	48	37
Prairie Rose	1998	60	14	27
Red Haw	1990	85	15	0
Red Haw	1991	57	43	0
Red Haw	1992	52	47	1
Red Haw	1993	57	39	4
Red Haw	1994	42	57	1
Red Haw	1995	30	70	0
Red Haw	1996	51	47	2
Red Haw	1997	65	33	2
Red Haw	1998	24	37	39
Red Haw	1999	22	63	15
Red Haw	2000	31	52	17
Red Haw	2001	22	40	38
Red Haw	2002			
Rock Creek	1999	26	34	40
Slip Bluff	1992	35	63	2
Slip Bluff	1993	57	41	2
Slip Bluff	1994	72	22	6
Slip Bluff	1996	74	24	2
Slip Bluff	1997	87	12	1
Smith	1992	15	43	37
Smith	1993	30	23	48
Smith	1994	35	26	39

Appendix C.—Continued.

Lake	Year	RSD-Stock (8-12 in)	RSD-Quality (12-15 in)	RSD-Preferred (15-20 in)
Smith	1995	66	28	6
Smith	1996	67	33	0
Smith	1997	54	43	4
Smith	1998	52	26	22
Swan	1989	13	67	20
Swan	1990	4	72	24
Swan	1991	38	39	23
Swan	1992	17	55	28
Swan	1993	36	35	29
Swan	1994	22	52	25
Swan	1995	17	44	40
Swan	1996	63	17	20
Union Grove	1993	30	35	35
Union Grove	1994	33	51	16
Union Grove	1995	42	53	5
Union Grove	1996	68	29	3
Union Grove	1997	20	58	22
Union Grove	1998	13	59	28
Union Grove	1999	19	37	44
Viking	1992	43	48	9
Viking	1993	56	38	7
Viking	1994	23	71	6
Viking	1995	21	64	16
Viking	1996	24	62	13
Viking	1997	47	26	28
Viking	1998	75	6	20
Williamson Pond	1991	83	1	16
Williamson Pond	1992	78	15	7
Williamson Pond	1994	27	62	11
Williamson Pond	1995	61	11	28
Williamson Pond	1996	77	8	15
Williamson Pond	1997	87	10	3
Williamson Pond	1998	79	13	8
Williamson Pond	1999	86	5	9
Williamson Pond	2000	81	17	2
Williamson Pond	2002	56	44	0
Yellow Smoke	1992	34	64	2
Yellow Smoke	1993	18	80	2
Yellow Smoke	1994	67	22	11
Yellow Smoke	1995	66	14	20
Yellow Smoke	1996	46	42	12
Yellow Smoke	1997	6	90	4
Yellow Smoke	1998	45	32	23
Yellow Smoke	1999	37	50	13
Yellow Smoke	2000	37	54	9

Appendix D.—Relative stock density (RSD) of crappies sampled from 23 study lakes using three size classes.

Lake	Year	RSD-Stock (5-8in)	RSD-Quality (8-10in)	RSD-Preferred (10-12in)
BLACK CRAPPIE				
Ahquabi	2001	0	76	24
Anita	1992	7	65	27
Anita	1993	23	54	23
Anita	1994	71	6	23
Anita	1995	58	37	5
Anita	1996	2	61	37
Anita	1997	3	3	95
Anita	1998	47	20	33
Green Valley	1993	36	45	19
Green Valley	1994	94	5	1
Green Valley	1995	53	44	3
Green Valley	1996	71	24	6
Green Valley	1997	33	67	0
Green Valley	1998	53	57	0
Green Valley	1999	43	56	1
Green Valley	2000	20	80	0
Hawthorn	1994	28	66	6
Hawthorn	1995	67	29	5
Hawthorn	1996	90	10	0
Hawthorn	1997	36	64	0
Hawthorn	1998	69	31	0
Iowa	1992	65	32	3
Iowa	1993	24	74	2
Iowa	1994	50	35	15
Iowa	1995	16	70	14
Iowa	1996	13	78	9
Iowa	1997	40	60	0
Iowa	1998	26	56	18
Iowa	1999	5	72	23
Keomah	1994	13	62	25
Keomah	1995	98	2	0
Keomah	1996	96	4	0
Keomah	1998	3	90	8
Mariposa	1994	56	42	2
Mariposa	1995	37	49	14
Mariposa	1996	100	0	0
Mariposa	1997	90	8	3
Mariposa	1998	66	32	2
Miami	1990	30	70	0
Miami	1991	26	72	2
Miami	1992	74	20	4
Miami	1993	36	64	0
Miami	1995	28	58	14
Miami	1996	76	24	0
Miami	1997	17	83	0
Miami	1998	68	29	3
Miami	2001	39	59	2
Miami	2002	35	63	2
Nine Eagles	1989	74	21	5
Nine Eagles	1990	65	20	14
Nine Eagles	1991	50	17	33

Appendix D.—Continued.

Lake	Year	RSD-Stock (5-8in)	RSD-Quality (8-10in)	RSD-Preferred (10-12in)
BLACK CRAPPIE				
Nine Eagles	1993	10	80	10
Nine Eagles	1995	39	56	6
Nine Eagles	1996	78	22	0
Nine Eagles	1998	87	13	0
Pahoja	1992	94	6	0
Pahoja	1993	14	86	0
Pahoja	1994	71	22	7
Pahoja	1996	9	92	0
Pahoja	1997	42	57	1
Prairie Rose	1994	53	46	1
Prairie Rose	1996	9	91	0
Prairie Rose	1997	48	52	0
Prairie Rose	1998	78	22	0
Red Haw	1992	25	67	8
Red Haw	1993	78	22	0
Red Haw	1995	0	4	96
Red Haw	1997	15	5	80
Red Haw	1998	50	50	8
Red Haw	2000	94	6	0
Red Haw	2001	81	19	0
Red Haw	2002			
Rock Creek	1999	88	12	0
Smith	1998	43	57	0
Slip Bluff	1992	81	18	1
Slip Bluff	1993	20	76	4
Slip Bluff	1994	27	69	4
Slip Bluff	1995	96	4	0
Slip Bluff	1996	72	28	0
Slip Bluff	1997	28	72	0
Swan	1989	62	37	1
Swan	1990	0	86	14
Swan	1991	12	44	44
Swan	1995	57	43	0
Swan	1996	36	64	0
Union Grove	1993	49	51	0
Union Grove	1994	79	21	0
Union Grove	1995	58	6	36
Union Grove	1996	77	23	0
Union Grove	1997	2	97	1
Union Grove	1998	17	11	71
Union Grove	1999	71	29	0
Viking	1992	87	7	6
BLACK CRAPPIE				
Viking	1993	27	73	0
Viking	1994	56	42	2
Viking	1996	72	22	7
Viking	1998	88	13	0
Williamson Pond	1991	42	57	1
Williamson Pond	1992	18	82	0
Williamson Pond	1995	26	74	0
Williamson Pond	1996	33	67	0
Williamson Pond	1997	38	50	13
Williamson Pond	1998	63	38	0

Appendix D.—Continued.

Lake	Year	RSD-Stock (5-8in)	RSD-Quality (8-10in)	RSD-Preferred (10-12in)
Williamson Pond	2000	63	13	24
Williamson Pond	2002	2	89	10
Yellow Smoke	1999	75	25	0
WHITE CRAPPIE				
Ahquabi	1997	50	42	8
Ahquabi	1998	13	88	0
Ahquabi	1999	15	77	8
Ahquabi	2001	0	56	44
Ahquabi	2002	24	71	5
Bob White	1994	83	17	0
Bob White	1996	64	19	17
Bob White	1997	15	78	7
Bob White	1998	39	53	8
Bob White	1999	72	24	4
Bob White	2000	73	16	11
Bob White	2001	83	12	5
Bob White	2002	76	11	14
Green Valley	1994	34	66	0
Green Valley	1995	0	42	58
Green Valley	1996	17	83	0
Green Valley	1997	38	54	9
Green Valley	1998	35	58	7
Green Valley	1999	15	48	37
Green Valley	2000	42	33	25
Hawthorn	1994	100	0	0
Hawthorn	1998	59	24	17
Iowa	1992	55	35	10
Iowa	1994	39	56	5
Iowa	1995	29	47	24
Iowa	1999	79	19	2
Keomah	1995	22	78	0
Mariposa	1994	27	73	0
Miami	1990	19	79	2
Miami	1991	15	73	12
Miami	1992	74	20	4
Miami	1993	8	72	20
Miami	1995	30	46	24
Miami	1996	75	16	9
Miami	1997	97	3	0
Miami	1998	35	65	0
Miami	1999	44	44	12
Miami	2001	46	48	6
WHITE CRAPPIE				
Miami	2002	48	42	10
Nine Eagles	1995	43	43	14
Rock Creek	1999	62	38	0
Slip Bluff	1992	14	63	6
Slip Bluff	1993	9	69	22
Slip Bluff	1994	89	7	4
Slip Bluff	1996	33	66	2
Smith	1992	100	0	0
Smith	1993	85	15	0
Smith	1995	84	14	2
Smith	1996	82	19	0

Appendix D.—Continued.

Lake	Year	RSD-Stock (5-8in)	RSD-Quality (8-10in)	RSD-Preferred (10-12in)
Smith	1997	94	6	0
Smith	1998	63	37	0
Union Grove	1999	71	29	0
Viking	1992	92	8	0
Viking	1995	2	74	24
Viking	1997	93	6	2
Williamson Pond	1991	62	38	0
Williamson Pond	1992	10	90	0
Williamson Pond	1994	65	31	4
Williamson Pond	1995	24	76	0
Williamson Pond	1996	18	82	0
Williamson Pond	1997	0	100	0
Williamson Pond	2000	82	18	0
Williamson Pond	2002	0	39	61

Appendix E.—Index of fish well-being based upon growth, body condition, and size structure of bluegills and largemouth bass sampled from 23 study lakes, one being "poorest" and five being "best".

Lake	Year	Bluegill	Largemouth Bass	Black Crappie	White Crappie
Ahquabi	1997	3.75	3.00	2.58	
Ahquabi	1998	2.25	3.67	1.33	
Ahquabi	1999	2.67	2.25		2.00
Ahquabi	2000	2.92	2.33		
Ahquabi	2001	3.75	2.67	2.5	3.42
Ahquabi	2002	2.25	2.33		2.17
Anita	1992	3.60	3.08	3.42	
Anita	1993	3.90	3.30	3.67	
Anita	1994	4.00	3.75	3.50	
Anita	1995	3.17	4.08	3.25	
Anita	1996	3.33	3.75	3.17	
Anita	1997	3.58	3.58	2.58	
Anita	1998	3.25	4.25		3.92
Anita	2001	3.42	2.08		
Bob White	1992	1.40	4.00		
Bob White	1993	2.20	3.30		
Bob White	1994	2.33	3.30		
Bob White	1995	2.33	2.83		
Bob White	1996	1.50	2.33		
Bob White	1997	2.92	2.67		1.92
Bob White	1998	1.83	2.58	2.17	
Bob White	1999	2.42	3.25		1.50
Bob White	2000	2.17	3.50		2.83
Bob White	2001	1.75	3.08		
Bob White	2002	1.67	3.25		2.08
Green Valley	1993	2.50	4.00	2.83	
Green Valley	1994	1.67	3.75	0.83	1.75
Green Valley	1995	1.67	3.92	2.67	2.50
Green Valley	1996	2.25	3.25	1.92	1.52
Green Valley	1997	3.17	3.50	2.00	2.83
Green Valley	1998	2.42	2.42	2.42	2.42
Green Valley	1999	2.58	3.92	2.42	2.25
Green Valley	2000	1.17	3.25	1.00	3.33
Hawthorn	1992	4.10	3.58		

Appendix E.—Continued.

Lake	Year	Bluegill	Largemouth Bass	Black Crappie	White Crappie
Hawthorn	1993	4.50	3.50		
Hawthorn	1994	3.33	1.92	2.08	0.83
Hawthorn	1995	3.92	3.08	2.58	
Hawthorn	1996	4.00	2.42	1.25	
Hawthorn	1997	3.67	3.00	2.00	
Hawthorn	1998	3.83	2.92	3.42	2.25
Iowa	1992	4.25	3.92	2.33	3.08
Iowa	1993	2.67	4.33	1.92	
Iowa	1994	3.50	4.50	2.83	2.75
Iowa	1995	3.25	3.75	2.58	2.67
Iowa	1996	3.50	4.00	2.08	
Iowa	1997	2.58	3.75	2.25	
Iowa	1998	2.58	4.08		3.17
Iowa	1999	1.92	4.00	2.00	2.83
Keomah	1993	4.25	3.42		
Keomah	1994	2.67	3.83		
Keomah	1995	2.50	3.92	0.83	1.67
Keomah	1996	2.42	3.00	1.33	
Keomah	1997	2.17	3.08		
Keomah	1998	2.17	4.08		1.92
Keomah	1999	2.92	3.33		
Keomah	2000	2.33	4.08		
Keomah	2002	3.17	4.50	1.67	
Lacey-Keosauqua	1992	4.50	1.33		
Lacey-Keosauqua	1993	4.00	0.67		
Lacey-Keosauqua	1994	3.42	2.17		
Lacey-Keosauqua	1995	3.75	2.17		
Lacey-Keosauqua	1997				
Mariposa	1992	3.40	3.33		
Mariposa	1993	2.33	3.42		
Mariposa	1994	2.83	3.33	2.92	2.75
Mariposa	1995	2.67	3.75	3.33	
Mariposa	1996	2.50	3.42	1.33	
Mariposa	1997	2.92	3.50	1.83	
Mariposa	1998	3.20	3.90	2.33	
Miami	1990	2.17	2.50	1.58	1.50
Miami	1991	1.58	2.42	1.42	2.33
Miami	1992	1.83	2.67	1.58	1.58
Miami	1993	1.58	1.42	1.75	2.00
Miami	1997	1.67	3.75	1.08	1.92
Miami	1998	2.42	3.08	2.58	2.08
Miami	1999	2.58	3.58		3.50
Miami	2000	2.42	4.00		
Miami	2001	2.33	4.00	2.50	2.83
Miami	2002	2.67	3.17	2.00	3.25
Nine Eagles	1989	3.08	1.92	1.67	
Nine Eagles	1990	3.08	2.16	2.50	
Nine Eagles	1991	2.75	2.58	2.50	
Nine Eagles	1993	3.82	2.17	2.00	
Nine Eagles	1994	--	1.33		
Nine Eagles	1995	2.25	0.83	2.25	2.75
Nine Eagles	1996	2.00	1.33	1.67	
Nine Eagles	1997	1.92	2.42		
Nine Eagles	1998	2.50	1.33		1.33

Appendix E.—Continued.

Lake	Year	Bluegill	Largemouth Bass	Black Crappie	White Crappie
Nine Eagles	1999	2.50	1.83		
Nine Eagles	2000	2.67	1.25		
Pahoja	1992	3.40	4.00	1.83	
Pahoja	1993	3.17	3.83	2.08	
Pahoja	1994	2.08	3.00	2.58	
Polmiller	1993	2.83	2.92		
Polmiller	1994	2.00	2.75		
Polmiller	1995	3.67	2.42		
Polmiller	1996	2.83	3.00		
Polmiller	1997	2.08	2.92		
Polmiller	1999	3.42	3.25		
Prairie Rose	1994	3.33	3.42	2.42	
Prairie Rose	1996	3.17	4.17	1.33	
Prairie Rose	1997	3.17	3.75	2.42	
Prairie Rose	1998	2.42	3.92		1.67
Red Haw	1990	3.92	1.67		
Red Haw	1991	4.50	2.42		
Red Haw	1992	4.00	2.25	2.92	
Red Haw	1993	3.33	3.50	2.17	
Red Haw	1994	3.42	1.67	1.83	
Red Haw	1995	2.33	1.42	1.83	
Red Haw	1996	4.00	2.00		
Red Haw	1997	3.92	2.00	1.92	
Red Haw	1998	2.08	2.75		2.42
Red Haw	1999	1.92	2.08		
Red Haw	2000	2.42	1.08		
Red Haw	2001	2.58	3.25	1.33	
Red Haw	2002				
Rock Creek	1999	3.00	3.92	1.83	2.75
Slip Bluff	1992	2.33	1.67	1.33	2.67
Slip Bluff	1993	1.75	2.92	1.08	2.92
Slip Bluff	1994	1.67	2.58		2.00
Slip Bluff	1996	2.17	2.00	1.17	2.50
Slip Bluff	1997	1.5	1.58	1.42	
Smith	1992	2.67	3.92		
Smith	1993	2.75	3.75		
Smith	1994	2.08	3.92		
Smith	1995	3.00	4.50	1.83	1.83
Smith	1996	3.33	3.42		1.83
Smith	1997	4.25	4.08	1.83	1.83
Smith	1998	2.83	4.25		2.67
Swan	1989	3.17	2.75	2.75	
Swan	1990	3.75	3.00	2.58	
Swan	1991	4.50	4.33	3.00	
Swan	1992	3.25	3.25	1.58	
Swan	1993	4.00	3.58	1.33	
Swan	1994	3.92	3.50	1.08	
Swan	1995	2.17	3.25	2.92	
Swan	1996	2.58	4.33	2.25	
Union Grove	1995	4.08	4.33	2.67	
Union Grove	1996	4.25	4.08	1.92	2.92
Union Grove	1997	4.00	3.83	1.33	
Union Grove	1998	4.00	3.50		2.00
Union Grove	1999	3.50	4.00	1.67	1.42

Appendix E.—Continued.

Lake	Year	Bluegill	Largemouth Bass	Black Crappie	White Crappie
Viking	1992	3.17	3.83	1.75	
Viking	1993	3.17	4.50	1.92	
Viking	1994	3.25	3.08	3.17	
Viking	1995	3.17	3.33		2.75
Viking	1996	3.17	3.08	2.08	
Viking	1997	3.50	4.00		1.33
Viking	1998	2.17	3.42		1.08
Williamson Pond	1991	1.08	2.83	1.92	1.50
Williamson Pond	1992	2.08	3.00	1.08	1.00
Williamson Pond	1994	2.50	3.75		1.83
Williamson Pond	1995	1.67	3.92	1.17	1.42
Williamson Pond	1996	2.08	3.50	1.75	
Williamson Pond	1997	3.50	3.00	2.58	1.08
Williamson Pond	1998	2.17	3.42		1.08
Williamson Pond	1999	2.92	3.42		
Williamson Pond	2000	1.83	3.08	2.50	2.58
Williamson Pond	2002	3.75	4.17	1.83	2.00
Yellow Smoke	1992	4.25	2.17		
Yellow Smoke	1993	2.83	1.83		
Yellow Smoke	1994	2.67	3.33		
Yellow Smoke	1995	2.58	3.17		
Yellow Smoke	1996	2.67	3.50		
Yellow Smoke	1997	2.67	3.50		
Yellow Smoke	1998	2.42	3.33		
Yellow Smoke	1999	3.08	3.08	2.42	
Yellow Smoke	2000	2.42	3.08		

Appendix F.—Water quality of 22 study lakes including turbidity (Secchi depth), chlorophyll *a,* phosphorus, and Carlson's Trophic State Index (TSI) where larger numbers indicate greater eutrophication.

Lake	Year	Secchi Disk Depth (ft)	Chlorophyll a mg/m^3	Phosphorus mg/m^3	Carlson's TSI
Ahquabi	1979	2.9	20	52	59.3
Ahquabi	1990	1.6	42	191	67.4
Ahquabi	1997	3.1	4	100	56.5
Ahquabi	1998	3.2	24	50	59.2
Ahquabi	1999	3.0	18	37	58.0
Ahquabi	2000	3.4	11	110	58.9
Ahquabi	2001	4.9	19	71	57.6
Ahquabi	2002	6.0	31	55	57.1
Anita	1979	2.3	47	56	62.8
Anita	1990	6.2	44	71	58.4
Anita	2000	2.8	17	75	60.1
Anita	2001	3.4	58	51	61.2
Anita	2002	2.6	55	60	62.7
Bobwhite	1979	0.7	13	167	68.4
Bobwhite	1990	0.3	7	474	72.8
Bobwhite	2000	1.0	11	362	67.9
Bobwhite	2001	0.2	17	345	70.5
Bobwhite	2002	0.7	10	165	67.2
Green Valley	1979	3.0	68	193	63.6
Green Valley	1990	3.3	38	136	62.8
Green Valley	2000	1.5	38	244	68.1
Green Valley	2001	4.2	34	87	60.3
Green Valley	2002	5.2	89	137	62.7
Hawthorn	1979	3.0	--	90	62.3
Hawthorn	1992	3.0	43	80	62.2
Hawthorn	2000	1.7	13	128	63.1
Hawthorn	2001	3.4	35	52	59.9
Hawthorn	2002	2.8	46	48	61.4
Iowa	1979	1.6	90	66	66.5
Iowa	1990	4.3	19	106	59.2
Iowa	2000	3.5	26	101	60.8
Iowa	2001	4.2	27	77	59.3
Iowa	2002	3.7	21	59	58.6
Keomah	1979	2.0	66	86	60.7
Keomah	1990	3.3	22	93	60.5
Keomah	2000	2.3	12	264	63.5
Keomah	2001	5.2	14	76	56.6
Keomah	2002	2.5	67	107	65.0
Lacey-Keosauqua	1979	7.2	11	30	52.0
Lacey-Keosauqua	1990	3.3	22	93	60.5
Lacey-Keosauqua	2000	8.7	--	88	54.5
Lacey-Keosauqua	2001	4.0	4	81	54.9
Lacey-Keosauqua	2002	--	--	--	--
Mariposa	1979	2.3	65	169	66.4
Mariposa	1990	2.0	26	234	65.8
Mariposa	2000	1.0	64	466	73.1
Mariposa	2001	1.7	65	140	67.4
Mariposa	2002	0.9	91	174	71.7

Appendix F.—Continued.

Lake	Year	Secchi Disk	Chlorophyll a	Phosphorus	Carlson's

		Depth (feet)	mg/m^3	mg/m^3	TSI
Miami	1979	2.6	43	57	62.0
Miami	1990	2.0	38	125	65.0
Miami	2000	1.7	18	210	65.3
Miami	2001	1.2	70	159	69.6
Miami	2002	2.5	37	106	63.4
Nine Eagles	1979	6.9	16	26	52.8
Nine Eagles	1990	4.3	25	49	57.9
Nine Eagles	2000	4.1	9	115	57.7
Nine Eagles	2001	4.8	7	37	53.4
Nine Eagles	2002	5.4	3	22	49.5
Pahoja	1979	4.9	18	744	63.4
Pahoja	1990	4.9	50	483	64.8
Pahoja	2000	2.1	81	352	69.4
Pahoja	2001	6.6	17	87	56.3
Pahoja	2002	4.5	35	59	58.9
Polmiller	1979	3.0	21	37	58.5
Polmiller	1990	4.6	28	90	59.4
Polmiller	2000	4.9	20	83	57.9
Polmiller	2001	8.0	5	34	50.1
Polmiller	2002	5.3	24	36	55.9
Prairie Rose	1979	2.0	39	95	59.5
Prairie Rose	1990	3.0	74	90	62.9
Prairie Rose	2000	1.7	23	122	64.5
Prairie Rose	2001	2.2	37	115	64.3
Prairie Rose	2002	2.3	59	70	63.9
Red Haw	1979	3.0	55	38	61.0
Red Haw	1990	12.1	3	46	47.6
Red Haw	1997	1.7	7	50	53.0
Red Haw	1998	2.8	23	50	60.0
Red Haw	1999	2.5	8	18	54.9
Red Haw	2000	4.5	10	73	56.5
Red Haw	2001	2.9	44	42	60.7
Red Haw	2002	2.7	30	41	60.0
Rock Creek	1974	0.5	---	67	65.0
Rock Creek	1979	0.5	76	119	68.0
Rock Creek	1990	0.5	25	167	66.0
Rock Creek	1999	0.9	12	264	62.0
Rock Creek	2000	4.0	15	74	57.9
Rock Creek	2001	4.4	29	73	59.1
Rock Creek	2002	2.2	27	57	61.5
Slip Bluff	1979	7.9	5	16	48.0
Slip Bluff	1990	2.3	9	74	59.4
Slip Bluff	2000	3.8	2	103	54.3
Slip Bluff	2001	3.4	4	94	56.0
Slip Bluff	2002	5.2	2	21	48.8
Smith	1979	1.6	92	110	67.8
Smith	1990	1.6	151	236	71.0
Smith	2000	1.2	41	254	69.6
Smith	2001	3.4	33	98	61.4
Smith	2002	5.5	28	267	61.3
Swan	1979	1.6	47	205	67.7

Appendix F.—Continued.

Lake	Year	Secchi Disk Depth (feet)	Chlorophyll a mg/m^3	Phosphorus mg/m^3	Carlson's TSI

Swan	1990	2.3	120	360	69.9
Swan	2000	0.3	273	752	83.4
Swan	2001	0.5	372	535	80.7
Swan	2002	0.5	81	327	75.6
Union Grove	1979	1.6	9	119	55.5
Union Grove	1982	1.0	29	155	62.0
Union Grove	1990	2.6	53	115	64.3
Union Grove	1992	0.8	36	17	58.0
Union Grove	1994	0.5	59	200	68.0
Union Grove	2000	1.9	42	210	66.7
Union Grove	2001	2.8	24	105	61.7
Union Grove	2002	1.3	51	137	68.2
Viking	1979	2.6	56	55	62.5
Viking	1990	4.9	63	90	61.1
Viking	2000	2.9	30	123	62.6
Viking	2001	3.8	56	93	62.1
Viking	2002	2.7	48	57	62.1
Williamson Pond	1979	2.6	21	56	60.1
Williamson Pond	1990	0.3	3	386	70.2
Williamson Pond	2000	1.7	10	444	65.6
Williamson Pond	2002	1.7	28	162	65.6
Yellow Smoke	1979	4.9	--	39	55.3
Yellow Smoke	1992	4.9	11	28	53.6
Yellow Smoke	2000	11.9	7	40	49.2
Yellow Smoke	2001	7.5	11	47	53.0
Yellow Smoke	2002	11.3	9	36	49.8